Report to the
Pierce's Disease and Glassy-winged Sharpshooter Board,
and
Pierce's Disease Advisory Task Force
on Research Recommendations Provided by
the National Academy of Sciences
and
American Vineyard Foundation

PD/GWSS Research Recommendations Subcommittee

November 2004

(slightly revised)

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Executive Summary

California's multi-billion dollar grape and wine industry is facing an unprecedented threat from the deadly combination of Pierce's disease (PD) and the glassy-winged sharpshooter (GWSS). This new pairing of a fatal plant disease with an aggressive new insect vector threatens grape production and its associated industries throughout the state. Recognizing that finding a solution to this problem requires the development of new knowledge and information, industry and government have made significant investments in PD/GWSS research. Ensuring that these research dollars are used to maximum benefit is of primary importance. Therefore, two reviews of the research effort were commissioned by the PD/GWSS Board. Over the course of one year, the American Vineyard Foundation (AVF) monitored research activities and interviewed researchers to search for consensus on research priorities and suggestions for improving research effectiveness. Similarly, the National Research Council of the National Academy of Sciences (NAS) convened a 12-member committee of experts who, during an 18-month project, used the refereed published literature and meetings with stakeholders to develop its report on research strategies and priorities. The reports from these two efforts have now both been issued, and it was the task of this subcommittee to review them and recommend how best to apply their findings and recommendations.

The NAS and AVF reports found that, overall, past and current investments in PD/GWSS research have been properly targeted. Since this pest problem must first be survived before it can be solved, there was recognition of the practicality and appropriateness of funding applied projects addressing immediate concerns as well as longer-term, more basic projects. Likewise, given the complex interconnectedness of biological systems, and the general acknowledgement that any solution will likely take the form of a suite of management options rather than one "silver bullet," the reports endorsed pursuing research and solutions on multiple fronts.

In this report, the subcommittee provides general overviews and discussions of the general recommendations from the NAS and AVF reports, as well as more specific point-by-point comments and responses to specific recommendations. Two of the main points that emerge are that rigorous standards of scientific review must be followed when selecting projects to fund, and that consolidation of the PD/GWSS research proposal solicitation and review process should be

considered by funding sponsors. These and other recommendations are highlighted and addressed in this report.

Overall, the NAS and AVF reports have provided good information on a very complex, dynamic, and challenging subject area. The different approaches followed in the two reports have yielded views of the issue from two perspectives, increasing the level of review and analysis. These reports can now be used as guidance documents to help direct the future investment of research dollars on PD/GWSS towards where they will do the most good.

The subcommittee is optimistic that, given time and adequate resources, solutions to the PD/GWSS problem will be developed. The leadership role taken by California's winegrape industry in sponsoring PD/GWSS research has not only helped further the cause of research, but also led to sizable and continuing levels of government participation in the fight against PD/GWSS. The net effect is that industry's contributions have been leveraged ten-fold, enabling the statewide program against PD/GWSS to continue to provide vital protection to one of the premiere agricultural industries of California.

Introduction and Background

Ever since the statewide effort against Pierce's disease and the glassy-winged sharpshooter began, it has been recognized that research holds the key to finding a solution to this serious threat facing California agriculture. Accordingly, significant resources have gone towards funding numerous research projects investigating diverse aspects of this complex pest situation. The first research projects initiated specifically against this newly-discovered pest situation were funded and launched in 2000, using $2.25 million in state general funds from Assembly Bill 1232. Shortly thereafter, additional research projects were funded using research dollars provided by USDA-APHIS-PPQ. Additional projects and funding accrued from the American Vineyard Foundation, California Citrus Research Board, Almond Board, USDA's Agricultural Research Service, local task forces, and the University of California. Passage of Assembly Bill 1394 in July 2001 established a new mechanism for funding research, through an annual assessment on winegrapes. To date this assessment has raised $13.9 million and funded nearly 100 research projects. It has also encouraged state and federal government to continue devoting resources and funding to the fight against PD/GWSS, to the point where industry funds have been matched ten-fold by government sources.

Several analyses have been conducted on PD/GWSS research needs and priorities. The first of these was conducted in late 1999, culminating in the issuance of the November 1999 *Report of CDFA's Glassy-winged Sharpshooter/Pierce's Disease Task Force*. This report provided a list of research priorities and objectives to address the disease and insect problem. In March 2000, the newly-formed Pierce's Disease Advisory Task Force issued its recommendations for research funding using AB 1232 monies, based on the November 1999 report and the response received to a recent request for proposals. In April 2000 the University of California issued the *Report of the Pierce's Disease Research and Emergency Response Task Force*, which identified research priorities and promising leads, reported on current UC activities, and identified other educational and information needs. A few years later, in November 2003, USDA-ARS would issue its study titled *Strategic Research Plan for* Xylella fastidiosa *Diseases and the Glassy-winged Sharpshooter*, which presented the ARS' assessment of research priorities and needs and described its current PD/GWSS research activities.

The tremendous amount of activity, multiple entities, and high stakes involved led to concerns about coordination of research activities, quality of supported research, communication of research results, and advisability of research funding decisions and other research-related actions. These concerns were addressed proactively by facilitating good communication among funding entities through information sharing, serving on each other's research selection panels, an annual research symposium with published proceedings, and enhanced scientific expertise on research screening panels. In addition, the PD/GWSS Board commissioned two studies to review, analyze, and/or monitor research activities and develop recommendations for optimizing the future investment of research dollars. These studies were conducted by the American Vineyard Foundation (one-year study; report provided January 2004), and the National Research Council of the National Academies (18-month study; pre-publication report released August 2004; final report released October 2004). The reports touched upon many aspects of the PD/GWSS research endeavor and provided information, commentary, and suggestions. By design and intent, the NAS report (164 pages) was more comprehensive than the AVF report (27 pages + 8 appendices), and each followed different approaches, with AVF relying heavily on interviews with researchers, while NAS relied upon a committee of 12 scientists from several different disciplines, who primarily used the refereed published literature.

This document highlights, comments, and suggests follow-up actions to the more salient points raised in the NAS and AVF reports, attempting to distill and convey the collective insights contained within them.

General Recommendations

This section discusses general topics covered in the two reports and provides comments and suggested actions. Responses to specific recommendations from each report are provided in Appendices A and B.

Selecting Quality Research Projects

One of the themes addressed by both reports is the importance of selecting and funding quality research projects. The AVF report stated:

> "Improve proposal-review process - need better reviewers, better science, less bias." [1]

The NAS report also discussed this issue, stating:

> "...the committee recommends that a mixture of projects be pursued, but above all that projects of the highest scientific quality in rationale, scope and design be selected." [2]

Ensuring that the proposal review process is effective at identifying superior research proposals is clearly important to achieving success against PD/GWSS in a timely manner. Establishing and maintaining a reliable, responsive system for reviewing research proposals should always be given a high priority.

Coordination and Consolidation of Research Funding Activities

Coordination of research funding activities was addressed in both reports. The AVF report stated that:

> "... *it will continue to be necessary for all funding agencies to coordinate funding with each other* in order to increase efficiency and effectiveness." [3]

The NAS report stated:

> "To ensure scientific rigor and enhance the coordination of the PD/GWSS research program, participating research sponsors should consolidate the processes for proposal solicitation and review." [4]

As mentioned in the **Introduction**, the importance of coordinating research funding has been recognized by state, federal, industry, and university partners since the start of the program. It has

[1] AVF report, page 24.
[2] NAS report, page 7.
[3] AVF report, page 18.
[4] NAS report, page 14.

been addressed through communication and information sharing among research sponsors, including having representatives of different funding agencies serve on each other's research screening panels. The NAS report acknowledges this:

> "The research program that has emerged from the exchange of information, data, and experiences among growers, county and state officials, and academic researchers reflects the various interests of the stakeholders in the PD problem." [5]

The PDCP followed up on the recommendation of the NAS to consolidate the proposal solicitation and review processes by initiating meetings among the research sponsors to explore and consider this idea. More information on this is forthcoming.

Identifying Promising Research Directions

Predicting where solutions will be found to a problem like PD/GWSS is clearly challenging. The AVF report noted that

> "... it is notoriously difficult to predict which scientific field will be successful," [6] and
>
> "... the future course of science is difficult to predict." [7]

With this in mind, it is recommended to retain a broad-based and flexible research plan and outlook, one which enables advancement of knowledge on several fronts and retains the ability to take advantage of new developments and opportunities.

Research Focus

Both reports looked at the issue of what the focus of future research should be. The AVF reported concluded that

> "Funding should increasingly concentrate on prevention and cure. The future funding focus should be roughly 15% for management, 60% for prevention, and 25% for cure." [8]

This recommendation presents a possible conflict with the NAS report, which stated that

> "... it is better to focus on management strategies instead of cures." [9]

This apparent conflict may be at least partially due to differences in word usage in the two reports, which can be expected when addressing topics where the terminology is not rigidly standardized. The "prevention-management-cure" (PMC) system can be used as one of potentially several ways

[5] NAS report, page 2.
[6] AVF report, page 13.
[7] AVF report, page 19.
[8] AVF report, page 4.
[9] NAS report, page 5.

to classify research projects and measure conformance of research project selection with established targets. Consistent with another recommendation from the AVF report, targeted PMC proportions can be reviewed and adjusted annually.

Anticipated Future Pest Developments

The question of what future developments to expect with PD/GWSS in the field was addressed or touched upon in both reports. The AVF report stated:

> "... sooner or later, GWSS will become established in some of the grape-production regions that currently are free from GWSS. ... GWSS is here to stay, and will affect more regions in the future rather than fewer." [10]

The NAS report touched upon the expected continuing presence of PD in California, indicating:

> "... measures that keep the disease in check are more realistic than are attempts to cure or eradicate PD ..." [11]

Clearly, eradication of the bacterium and/or the sharpshooter from California is not deemed likely. Consequently, it is important that solutions be found which enable production of winegrapes in areas where the pests are present, rather than relying upon complete absence of the pests to provide long-term protection.

Research Timeframes

The topic of research timeframes actually covers two ideas: the amount of time expected to be needed for research efforts to lead to usable results, and deciding the proper mix of short, medium, and long-term projects and solutions.

The need to continue the research effort against PD/GWSS was expressed in both reports. The AVF report recommended:

> "Ensure that research funding continues at least through March 2011. Researchers will need at least this much time to develop effective tactics for prevention and cure." [12]

The NAS report also indicated that more time is needed:

[10] AVF report, page 17.
[11] NAS report, page 5.
[12] AVF report, page 4.

> "Currently funded research encompass a range of approaches for PD/GWSS management, some of which will require years of study and field verification before commercial acceptance is possible." [13]

The recent passage of SB 1650 will provide additional time and resources to direct against the PD/GWSS problem (this is contingent upon the grower vote upholding the legislation). This time extension in the research effort is expected to result in significant progress on the many research fronts being pursued.

Both reports considered the issue of short, medium, and long-term projects and results. They both recognized that while long-term solutions are the desired eventual goal, it would not be advisable to invest wholly in long-term projects if needed short-term protection of vineyards was ignored. Consequently, appropriate mixes of short, medium, and long-term projects were recommended. Follow-up clarification on this issue may be helpful, in terms of distinguishing short, medium, and long-term projects and solutions, and the relationships between them (i.e., is there an underlying assumption that short-term studies will produce short-term solutions, medium-term studies will produce medium-term solutions, etc.?).

Ecologically Based Pest Management

The NAS report advocates using an ecologically based pest management (EBPM) approach to managing the Pierce's disease problem, stating:

> "... it is assumed that the overall approach to the resolution of the problem will involve implementation of an ecologically based pest management program." [14]

The report defines EBPM as:

> "... the release of living predatory, parasitic, pathogenic, or antagonistic organisms (biological control organisms), the deployment of biologically derived products, such as toxins or semiochemicals (biological control products), and the planting of resistant crop varieties (resistant plants)." [15]

The conclusion that effective PD/GWSS management will derive from a combination of methods and tactics rather than a single practice is likely to be true, although development of acceptable resistant or tolerant varieties could lessen the need to employ additional pest management

[13] NAS report, page 12.
[14] NAS report, page 55.
[15] NAS report, page 55, referencing National Research Council, National Academy of Sciences. 1996. Ecologically Based Pest Management: New Solutions for a New Century. Wash., D.C.: National Academies Press.

practices. Although EBPM seems to hold a preference against the use of conventional pesticides, in the case of PD/GWSS, such materials likely will continue to play an important role in management of these pests. Regardless, this recommendation is consistent with maintaining a broad research portfolio and multi-pronged approach towards dealing with PD/GWSS.

Economic Analysis

The need for economic analysis is mentioned in both reports. The AVF report states that:

> "Other key research gaps include: ... Economics. In particular, cost-benefit analyses of actual and proposed pest-control tactics." [16]

The NAS report contains several recommendations touching upon economic analyses. These include:

> "Assess the economic feasibility of specific biological and chemical control methods and strategies."
>
> "An economic analysis, including environmental impacts, should be [conducted] for all potential management strategies and outcomes."
>
> "The long-term research agenda should include economic analyses of policy regulations, incentives, and institutions to limit introduction and movement of PD vectors." [17]

Some information pertaining to economic and environmental analysis of grape production and the PD/GWSS problem is already available. This includes a preliminary study by Dr. Jerome Siebert on the economic impact of Pierce's disease on the California grape industry; economic analyses (economic impact statements) prepared when the PD/GWSS regulations were promulgated; studies by the University of California on the costs of establishing and maintaining vineyards; and the PDCP environmental impact report. The PD/GWSS Board could solicit a comprehensive economic and environmental analysis of all potential management strategies and outcomes (which would require that all strategies and outcomes first be identified), or alternatively, request researchers to include economic and environmental analysis in their individual proposals. However, it may be difficult for prospective analyses to accurately quantify actual future costs of strategies and methods, since later development of successful approaches and marketing decisions may influence actual pricing structures of PD/GWSS solutions.

[16] AVF report, page 11.
[17] NAS report, page 13.

Specific Recommended Areas of Research

The majority of recommendations in the NAS report identify specific areas in which additional research is recommended [see “List of Recommendations” (Appendix C) and “List of Key Recommendations” (Appendix D)]. The recommended actions for each of these is similar:

1. Highlight these areas in future requests for research proposals;
2. Ask research screening panels to give priority to proposals in these fields;
3. Actively seek out researchers to perform needed studies in areas not being addressed.

These actions are contingent upon the determination that (i) the identified research areas and approaches continue to hold potential for helping solve the Pierce’s disease problem, and (ii) that there is more useful information to be collected in that particular field. These considerations are implicit in the research screening process conducted by research review panels, but reminders could be added to the instructions for reviewers to ensure these thoughts remain prominent.

The list of recent PD/GWSS studies has been compared with the NAS list of key recommendations (Appendix D) and the list of AVF research categories (Appendix E), to determine to what extent the current research portfolio is already addressing the recommended research areas. This information is presented in Appendix F.

Conclusion

Overall, the NAS and AVF reports have provided good information on a very complex, dynamic, and challenging subject area. The different approaches followed in the two reports have yielded views of the issue from two perspectives, increasing the level of review and analysis. These reports can now be used as guidance documents to help direct the future investment of research dollars on PD/GWSS towards where they will do the most good.

Appendices

APPENDIX A

Responses to Specific Recommendations in the AVF Report

This appendix presents the specific recommendations from the AVF report and provides comments, updates, and recommended actions concerning them.

Table I. To improve the future focus of research

Recommendation	Comments/Action
1. Ensure that research funding continues at least through March 2011. Researchers will need at least this much time to develop effective tactics for prevention and cure.	1a. Continuation of funding was pursued via legislation (SB 1650, approved September 10, 2004). This legislation extended the PD/GWSS winegrape assessment and Board to March 1, 2011 (pending a favorable grower vote) and allows funds to be used beyond the legislation's sunset date.
2. Funding should increasingly concentrate on prevention and cure. The future funding focus should be roughly 15% for management, 60% for prevention, and 25% for cure.	2a. The NAS report states that "it is better to focus on the concept of management strategies instead of cures," which seems to disagree with this recommendation. Nevertheless, the selection process can include classifying projects into "prevention-management-cure" categories and then aiming for current recommended funding proportions (see recommendation 5).
3. Within prevention, funding should concentrate on developing resistant scions and rootstocks. This includes preliminary research on the mechanisms and genetic control of resistance.	3a. The recommended emphasis on funding for prevention-related projects can be provided to research screening panels as a guideline.
4. Within cure, there is no consensus among researchers about the most promising tactics. So for now, the funding should be spread among several tactics to reduce risk.	4a. The recommended approach to funding cure-related projects can be provided to research screening panels as a guideline.

Recommendation	Comments/Action
5. The funding focus should be reviewed annually, and coordinated with other funders.	5a. An annual review of the funding focus can be incorporated into the annual RFP revision process. Resulting funding focus priorities can be communicated to research screening panels. 5b. Coordination among funding agencies via communication, information sharing, and participation on research screening panels should continue. As recommended by the NAS, consolidation of research proposal solicitation and review processes should be considered.

Table II. To improve research performance

Recommendation	Comments/Action
1. Organize the research portfolio into a small number of multi-year programs. Each program would work to produce a particular pest-control tactic (for example, resistant rootstocks).	1a. Multi-researcher "umbrella" projects were tried earlier and proved difficult for researchers to administer, leading to their break-up into smaller projects. It can also be difficult to review and assess the progress of such projects. 1b. A statement can be added to the RFP encouraging collaboration. 1c. Research screening panels can be asked to identify collaboration opportunities, to be followed up with the researchers. 1d. Research screening panels can be asked to identify and recommend promising multi-year projects.
2. Assign a person, or organization, to manage each research program. Whoever undertakes this managerial role should take a results-oriented, "venture capitalist" approach.	2a. The PD/GWSS Board is pursuing contracting with AVF to monitor and coordinate PD/GWSS research activities and develop future funding recommendations.
3. Fund informal meetings/retreats to encourage collaboration among researchers.	3a. The PD/GWSS Board may wish to further evaluate this idea in terms of projected costs and benefits.

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Recommendation	Comments/Action
4. Collaborate with Brazilian researchers; they are highly skilled but have been underutilized.	4a. A special category can be added to the next call for research proposals, specifically soliciting collaborative projects with Brazilian researchers.
5. Improve policies and procedures of CDFA's competitive grant process. In particular, we strongly support multi-year funding, coupled with close monitoring.	5a. Research screening panels can be asked to identify and recommend promising multi-year projects. 5b. The PD/GWSS Board is pursuing hiring AVF to monitor PD/GWSS research activity (see 2a). 5c. See additional related recommendations in Table III.
6. Earmark some funds for contract research, in case there is an important research question for which no appropriate research proposal was received.	6a. A line item for funds for contract research can be added to the PD/GWSS Board's annual budget. 6b. A research advisory group can be asked to identify important research questions not being pursued. 6c. The PDCP can pursue obtaining contract research services for unaddressed research questions identified by the research advisory group.
7. Conduct public education programs to encourage continued public funding. This would be a small but useful step towards reversing the decline in institutional support that threatens California's capacity for agricultural research.	7a. The PD/GWSS Board is currently funding an outreach program focused primarily at winegrape stakeholders. This program could be expanded to include the general public. 7b. Current industry, government, and university outreach efforts could be revitalized.

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Table III. To improve the competitive grant process

Recommendation	Comments/Action
1. Improve communication about grant requirements and procedures.	1a. The current process involves developing information with input from advisory groups, then e-mailing it directly to researchers and posting it on the website. Opportunities and suggestions for enhancing this process can be sought and implemented when found. 1b. The 2004 PD Research Symposium will include a panel presentation on research funding.
2. Improve proposal-review process -- need better reviewers, better science, less bias. The authors recommend a dual review process that uses both a panel of California reviewers, and an independent panel of national (non-California) reviewers.	2a. The 2004 research proposal review process was expanded to include input from 28 outside reviewers. This enhanced the review process and could be repeated in subsequent years.
3. Increase duration of funding -- researchers need at least 2-3 years of reliable funding in order to recruit and retain support staff, graduate students, and post-doctoral research associates.	3a. Research screening panels can be asked to identify and recommend promising multi-year projects. 3b. Continuation of multi-year funding should be contingent upon satisfactory progress being made, and the project remaining relevant to solving the PD/GWSS problem.
4. Accelerate the transfer of funds / execution of grant contracts.	4a. The research contract process can be reviewed for opportunities to accelerate the process. 4b. Note: Research funds are not transferred to research institutions. Instead, contracts and accounts are set up, and then invoices are paid in arrears for actual expenses incurred.
5. Allow moving funds among line items to accommodate legitimate changes in research focus based on results to date.	5a. This is being done.
6. Allow rolling over unspent funds to subsequent FYs to accommodate legitimate changes in research focus based on results to date.	6a. This is being done.

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Recommendation	Comments/Action
7. Develop an out-of-cycle "fast-track fund" for new ideas or emergencies.	7a. A line item for funds for new ideas, emergencies, or contract research can be added to the PD/GWSS Board's annual budget. 7b. Related to this, a process is in place for quickly evaluating proposals which are received out-of-cycle and are deemed urgent by submitters and/or stakeholders.

APPENDIX B

Responses to Specific Recommendations in the NAS Report

This appendix presents the specific recommendations from the NAS report and provides comments, updates, and recommended actions concerning them.

Chapter 2: Developing Priorities for Research

Recommendation	Comments/Recommended Actions
2.1. To ensure scientific rigor and enhance the coordination of the PD/GWSS research program, participating research sponsors should consolidate the processes for proposal solicitation and review.	2.1a. The PDCP has initiated meetings among the research sponsors to explore and consider the idea of consolidating research proposal solicitation and review processes.
2.2. Research priorities should be developed according to their ability to meet two criteria: the predicted ability of the approach to contribute to PD/GWSS management, and its sustainability. The committee recommends a balance among short-, medium-, and long-term research projects to ensure the development of sustainable management approaches is achieved.	2.2a. The criteria of (i) sustainability of approaches and (ii) the likelihood of their contributing to PD/GWSS management can be used in the future in developing research priorities. 2.2b. Research screening panels can be advised to seek a balance of short, medium, and long-term research projects. 2.2c. To assist with implementing this recommendation, clarification should be sought on identifying and distinguishing short, medium, and long-term projects and solutions, and the relationship between them.
2.3. An economic analysis including a study of environmental impacts should be conducted for *all* potential management strategies and outcomes.	2.3a. Step 1 would be to identify all potential management strategies and outcomes. 2.3b. For step 2, the Board could solicit a comprehensive economic and environmental analysis of the list developed in step 1, or alternatively, request researchers to discuss these points in their individual proposals. 2.3b. The comprehensive environmental impact report prepared for the program may fulfill some of this recommendation.

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Recommendation	Comments/Recommended Actions
2.4. The long-term research agenda should include economic analyses of policy regulations, incentives, and institutions to limit introduction and movement of PD vectors.	2.4a. Economic analysis of the PD/GWSS regulations was conducted as part of the regulation promulgation process. Cost-benefit and similar economic analyses of the pest prevention system have been conducted. This recommendation may be outside the scope of the PD/GWSS research effort.

Remaining Recommendations

The remainder of the recommendations in the NAS report identify specific areas in which additional research is recommended [see "List of Recommendations" (Appendix C) and "List of Key Recommendations" (Appendix D)]. The recommended actions for each of these is similar, i.e.:

1. Highlight these areas in future requests for research proposals;
2. Ask research screening panels to give priority to proposals in these fields;
3. Actively seek out researchers to perform needed studies in areas not being addressed.

Therefore, a point-by-point evaluation and response to each recommendation is not necessary. The list of recent PD/GWSS studies has been compared with the NAS list of recommended research areas, to determine to what extent the current research portfolio is already addressing the recommended research areas. This information is presented in Appendix F.

APPENDIX C

List of Recommendations
-- NAS Report --

This appendix presents the recommendations of the NAS report, organized in the sequence and numbering system used in the report. As can be seen, the NAS report numbered the recommendations according to the chapter and order they appeared in. Also, each recommendation was given a category, based upon (a) the likelihood of research in that subject area contributing to successful PD/GWSS management, and (b) the sustainability of developed products and approaches. The four categories are:

- Category 1: The research option holds reasonable promise of generating successful tools for management of PD/GWSS, either in the short term or the long term.
- Category 2: The research approach looks promising, but, either because of insufficient data or because of inconclusive results, it is difficult to predict whether it will lead to successful applications for management.
- Category 3: The research can produce data and results that are promising for successful management of PD/GWSS, but because of its complexity and the technology required, it would be prohibitively expensive for any one funding source to manage.
- Category 4: The research approach does not show promise, even in the long term, for PD/GWSS management.

Chapter 2: Developing Priorities for Research

Recommendation 2.1: To ensure scientific rigor and enhance the coordination of the PD/GWSS research program, participating research sponsors should consolidate the processes for proposal solicitation and review.

Recommendation 2.2: Research priorities should be developed according to their ability to meet two criteria: the predicted ability of the approach to contribute to PD/GWSS management and its sustainability. The committee recommends a balance among short-, medium-, and long-term research projects to ensure the development of sustainable management approaches is achieved.

Recommendation 2.3: An economic analysis including a study of environmental impacts should be conducted for *all* potential management strategies and outcomes. (Category 1)

Recommendation 2.4: The long term research agenda should include economic analyses of policy regulations, incentives, and institutions to limit introduction and movement of PD vectors. (Category 2)

Chapter 3: Host-Vector Interaction

Recommendation 3.1: Studies that provide more information about sharpshooter feeding, host-finding behavior, host plant preferences, and the factors that influence reproductive success and natural-enemy-caused mortality are needed. The potential effects of *Xf* infection on sharpshooter behavior and performance should be included in those studies. These factors must be examined with statistical rigor so that the results are reliable. (Category 1)

Recommendation 3.2: All the modern chemical, molecular, ecological, and statistical tools available to scientists should be used to identify mechanistic bases of grapevine resistance to xylem-feeding leafhoppers. Studies should be done in the ecosystem and consider multitrophic interactions among plants, insect pests, and natural enemies (predators and parasites), and they should include both insect- and *Xf*-induced changes in plant quality. (Category 2)

Recommendation 3.3: Host-plant resistance should be emphasized as a component of ecologically based insect management strategies in the grapevine-sharpshooter-*Xf* system. Methods for manipulating grapevine resistance should be developed for experimental use to identify key resistance traits and with an eye toward

eventual deployment. The methods should allow work with genetically transformed plant material, use of chemical or other elicitors, and cultivation practices. (Category 2)

Recommendation 3.4: Detailed, quantitative studies should examine leafhopper performance (survivorship, fecundity, development time) on and preference for a broad range of potential ground cover crops. (Category 2)

Recommendation 3.5: The feasibility of using carefully selected cover crops in vineyards to reduce sharpshooter colonization to grape should be investigated. (Category 2)

Recommendation 3.6: Potential ground cover crops should be screened for the capacity to develop epidemiologically significant populations of *Xf.* (Category 2)

Recommendation 3.7: Detailed, quantitative studies should examine leafhopper preference for potential host plants in the context of natural assemblages of hosts in the field. Studies of leafhopper performance on a broad range of potential host plants are essential to elucidate host ranges. (Category 2)

Recommendation 3.8: The plant-to-plant movement of GWSS at multiple scales should be examined throughout the year to identify long-range seasonal and "trivial" movements that lead to disease spread. (Category 2)

Recommendation 3.9: Sharpshooter host plants should be screened for their capacity to develop epidemiologically significant populations of *Xf* and examined for effective transmission rates from host to grape. (Category 2)

Recommendation 3.10: After the epidemiologically important noncrop host plants of the vectors are identified, the ecological and socioeconomic barriers to removal of those plants from areas that influence disease prevalence in grapes should be explored. (Category 2)

Recommendation 3.11: Basic and applied research should establish protocols for the effective selection of natural enemies, develop strategies to increase the success of inoculative releases of parasitoids, and rigorously evaluate the effectiveness of released natural enemies. (Category 2)

Recommendation 3.12: Support for classical biological control (inoculative releases) is preferred over augmentation if inoculative releases result in self-sustaining populations and can be shown to be less costly than augmentation. (Category 2)

Recommendation 3.13: Research should assess the economic feasibility of biological control tactics and strategies. (Category 2)

Recommendation 3.14: Biological control tactics within EBPM schemes should be evaluated within the context of working economic thresholds. (Category 2)

Recommendation 3.15: Research on the use of biological control agents (predators and parasitoids) should be a priority in commercial vineyards where there is a minimal use of insecticides, the use of selective insecticides that are nontoxic to natural enemies are used, or where the timing of insecticide use is such that mortality to natural enemies is minimal. Similarly, research should be supported that advances the use of biological control agents in areas and habitats where insecticide use can be severely restricted or eliminated. Areas for study could include riparian habitats, watershed areas, wetlands, and urban and suburban green areas. (Category 2)

Recommendation 3.16: Control strategies should be pursued that limit the use of insecticides to sustainable formulations that are minimally incompatible with ecologically based approaches to pest management. A premium should be set on minimizing the negative consequences of pesticide use for human health and environmental quality.

Recommendation 3.17: Research should assess the economic feasibility of specific chemical control strategies and develop decision and cost models to guide growers in setting up chemical control methods for GWSS. (Category 1)

Chapter 4: Plant-Pathogen Interaction

Recommendation 4.1: A systematic analysis of *Xf* pathogenicity should be accomplished with a combination of biochemical, genetic, and genomic analyses. Such research lends itself to a collaborative approach. (Category 2)

Recommendation 4.2: As with the pathogen, systematic and global approaches to address host plant responses (disease or defense) to pathogen invasion are essential to identify important plant defense factors. However, until the sequence of the grape genome is available and until other tools, such as grapevine mutants for dissection of defense responses, are available, that approach should be viewed as a long-term and expensive effort. (Category 3)

Recommendation 4.3: Host plant resistance to *Xf*, whether quantitative or qualitative, is important to long-term management of the disease. Immediate emphasis should be placed on identification and characterization of the genetic basis for resistance to *Xf* in host plants. Characterization of the genetic loci and biochemical mechanisms responsible for resistance will facilitate classical approaches (which use molecular markers) and transgenic breeding to create *Xf*-resistant plants. (Category 2)

Recommendation 4.4: Improvements in tissue transformation systems and in the ability to regenerate plants from transformed tissue have made transgenic technologies increasingly feasible, although the availability of genes of known function that could be introduced to target desired effects is limited. In the long-term, however, transgenic technology could hold promise for improving resistance to *Xf*. (Category 2)

Recommendation 4.5: Long-term projects should focus on identification of pathogen targets for existing or novel chemical control approaches or for the means to stimulate or alter host defense response pathways. (Category 2)

Recommendation 4.6: Research should determine the efficacy and the economic and environmental feasibility of manipulating alternative hosts for PD management. (Category 2)

Chapter 5: Vector-Pathogen Interaction

Recommendation 5.1: Research should be done on the transmission biology of the disease system, including acquisition from and inoculation to alternative hosts and acquisition from and inoculation to dormant grapevines. (Category 2)

Recommendation 5.2: Research should be done on the determinants of transmission efficiency, including attachment and reproduction of *Xf* in GWSS. (Category 2)

Recommendation 5.3: A subset of studies of the vector should explore the effects of *Xf* on vector survivorship, fecundity, and population growth rates. (Category 2)

Recommendation 5-4: A subset of studies of the vector should explore the effects of *Xf* on vector behavior, including movement and attraction to infected hosts. (Category 2)

APPENDIX D

List of Key Recommendations
-- NAS Report --

The NAS report provided two sets of recommendations: those presented and developed in each chapter of the report (reproduced in Appendix C of this report), and another set under the heading "Key Recommendations" in the Executive Summary of the report. The latter set is presented here. Note that this list was used for categorizing the PD/GWSS research projects listed in Appendix F of this report.

Similar to the first set of recommendations, each key recommendation was given a category, based upon (a) the likelihood of research in that subject area contributing to successful PD/GWSS management, and (b) the sustainability of developed products and approaches. The four categories are:

- Category 1: The research option holds reasonable promise of generating successful tools for management of PD/GWSS, either in the short term or the long term.
- Category 2: The research approach looks promising, but, either because of insufficient data or because of inconclusive results, it is difficult to predict whether it will lead to successful applications for management.
- Category 3: The research can produce data and results that are promising for successful management of PD/GWSS, but because of its complexity and the technology required, it would be prohibitively expensive for any one funding source to manage.
- Category 4: The research approach does not show promise, even in the long term, for PD/GWSS management.

1. **Interactions of Host, Pathogen, and Vector** -- the committee makes the following recommendations for research:
    a. Determine the genetic, biochemical, and physiologic basis for *Xf* virulence, pathogenicity, transmission, and survival. (Category 2)
    b. Determine genetic, biochemical, and physiologic basis for GWSS herbivory and disease vectoring. (Category 2)
    c. Determine the genetic, biochemical, and physiologic basis for host plant factors that influence attraction, repulsion, survival, or inhibition of GWSS or *Xf*. (Category 2)
2. **Host Plant Resistance to Pathogen and Pest** -- the committee recommends the following research:
    a. Determine the genetic and mechanistic bases for grapevine resistance to *Xf* and GWSS. (Category 2)
    b. Develop and improve methods for manipulating grapevine resistance to *Xf* and GWSS. (Category 2)
3. **Biological Control** -- the committee makes the following recommendations:
    a. Research is needed to advance the use of classical biological control (predators and parasitoids) of the insect. (Category 2)
        i. Establishment of protocols for the effective selection of natural enemies.
        ii. Development of strategies that will increase the success of inoculative releases of parasitoids.
        iii. Rigorous evaluation of the effectiveness of the released natural enemies.
    a. *Studies on the biological control of the pathogen.* [1]
4. **Vegetation Management** -- the committee provides the following recommendations:
    a. Research should advance the use of vegetation management to reduce populations of GWSS and and *Xf*. (Category 2)

[1] This category was added to the list; it was not included in the NAS report's list of key recommendations.

5. **Chemical Control** -- research on chemicals should focus on the following areas: (Category 4)
    a. Identify and develop more efficient means of delivery of the chemical to the target.
    b. Identify novel pathogen targets for which highly specific chemicals can be identified or developed.
    c. Determine the social and environmental consequences of using these compounds.
    d. Conduct an economic assessment of insecticide effectiveness within an ecologically based pest management scheme.
6. **Economic Feasibility** -- the committee recommends examples of economic research projects needed.
    a. Assess the economic feasibility of specific biological and chemical control methods and strategies. (Category 1)
    b. An economic analysis, including environmental impacts, should be conducted for all potential management strategies and outcomes. (Category 1)
    c. The long-term research agenda should include economic analyses of policy regulations, incentives, and institutions to limit introduction and movement of PD vectors. (Category 2)

APPENDIX E

PD/GWSS Research Categories
-- AVF Report --

This appendix presents the organization scheme used in the AVF report for categorizing PD/GWSS research projects. Note that this list was used for categorizing the PD/GWSS research projects listed in Appendix F of this report.

1 --- Biology/Ecology of the Crop

2 --- Biology/Ecology of the Vectors

- 2.1 --- Vector basic biology
- 2.2 --- Insect/plant interactions & vector population ecology

3 --- Biology/Ecology of the Pathogen

- 3.1 --- *Xf* genetics
- 3.2 --- Bacteria/plant & bacteria/insect interactions
- 3.3 --- Epidemiology of Xf diseases

4 --- Monitoring & Action Thresholds

- 4.1 --- Vector monitoring & action thresholds
- 4.2 --- *Xf* monitoring & action thresholds

5 --- Control Tactics & Strategies

- 5.1 --- Vector biological control
- 5.2 --- *Xf* biological control
- 5.3 --- Vector chemical control
- 5.4 --- *Xf* chemical control
- 5.5 --- Cultural, physical, & behavioral control
- 5.6 --- Resistance to *Xf* diseases

APPENDIX F

Recent PD/GWSS Research Projects

Note: This list provides information on recent PD/GWSS research projects and researchers, as well as the recommended NAS/AVF research categories which the projects fall into. It includes PD/GWSS research projects conducted in 2000 and later, and journal articles published in 2003 or 2004 that were not cited in the NAS report. Research projects were included regardless of funding source. The list was prepared to help gauge recent progress at conducting research in recommended research subject areas. See Appendices D and E for lists of NAS and AVF research category codes.

Line Number	Principal Investigators	Title	Citation	Year	Research Categories	
					NAS	AVF
1	Adams	Identification of molecular markers in the grapevine's response to infection by *Xf.*	Proceedings, PD Research Symposium	2001	2a	3.2
2	Akey, Blua, Henneberry	Control of immature and adult GWSS: evaluation of biorational and conventional insecticides.	Proceedings, PD Research Symposium	2002	5b	5.3
3	Akey, Blua, Henneberry	Control of immature and adult GWSS: evaluation of biorational insecticides for organic use.	Proceedings, PD Research Symposium	2003	5b	5.1
4	Akey, Blua, Henneberry	Potential of conventional and biorational insecticides for GWSS control.	Proceedings, PD Research Symposium	2001	5b	5.1
5	Almeida, Mann, Purcell	*Xf* cultivation on a minimal solid defined medium.	Current Microbiol. 48: 368-372.	2004	1a	3.2
6	Almeida, Purcell	Biological traits of *Xf* strains from grape and almonds.	Appl. Environ. Microbiol. 69: 7447-7452.	2003	1a	3.3
7	Almeida, Purcell	*Homalodisca coagulata* transmission of *Xf* to almond.	Plant Disease 87: 1255-1259.	2003	1b	2.2
8	Alves, et al.	Relationship between leaf symptoms and the proportions of xylem-colonized vessels of plum, coffee and citrus colonized by *Xf*.	Phytopathology 93S: 4.	2003	1a	3.2, 3.3
9	Alves, Kitajima, Leite	Interaction of *Xf* with different cultivars of *Nicotiana tabacum*: A comparison of colonization patterns.	J. Phytopathology 151: 500-506.	2003	1a	3.3, 3.2
10	Alves, Marucci, Lopes, Leite	Leaf symptoms on plum, coffee, and citrus and the relationship with the extent of xylem vessels colonized by *Xf*.	J. Phytopathology 152(5): 291-297.	2004	1a	3.3, 3.2
11	Al-Wahaibi	Studies on two *Homalodisca* species in southern California: biology of the egg stage, host plant, and temporal effects on oviposition and associated parasitism, and the biology and ecology of two of their egg parasitoids, *Ufens* A and *Ufens* B.	PhD thesis; UC Riverside	2004	1b, 3a	2.1, 5.2, 2.2
12	Al-Wahaibi, Morse	*Homalodisca coagulata* embryonic development at constant temperatures.	Florida Entomol. 86(4): 477-478.	2003	1b	2.1, 2.2
13	Andersen	Biological, cultural, genetic, and chemical control of PD. Objective 7: xylem chemistry mediation of resistance to PD.	Proceedings, PD Research Symposium	2002, 2003	2a, 5b	5.4, 5.2, 5.6
14	Andersen, Brodbeck, Mizell	Plant and insect characteristics in response to increasing density of *Homalodisca coagulata* on three host species: a quantification of assimilate extraction.	Entomologia Experimentalis et Applicata 107(1): 57-68.	2003	1a, 1b	2.2

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Line Number	Principal Investigators	Title	Citation	Year	Research Categories	
					NAS	AVF
15	Azzoni, et al.	Expression and purification of a small heat shock protein from the plant pathogen *Xf*.	Protein Expression & Purification 33(2): 297-303.	2004	1a, 3b	3.1
16	Backus	Sharpshooter feeding behavior in relation to transmission of the PD bacterium.	Proceedings, PD Research Symposium	2001, 2002, 2003	1b	3.3, 2.2
17	Backus, et al.	Sharpshooter feeding behavior in relation to inoculation of Pierce's disease bacterium, *Xf*, in grape.	Phytopathology 93S: 6.	2003	1b	3.2
18	Backus, Miller	Where, when, and how do ingestion and other feeding behaviors of GWSS allow inoculation of *Xf*?			1b	3.3, 2.2
19	Bartels, Wendel, Ciomperlik	Spatial distribution of GWSS in a diverse agricultural system, and correlation between direct observations and sticky trap data.	Proceedings, PD Research Symposium	2002	1c	2.1, 5.1
20	Baumann et al.	The complete sequence of the mitochondrion of GWSS.			1	2.2
21	Baumgartner	Biological, cultural, genetic, and chemical control of PD: significance of riparian plants in the epidemiology of PD.	Proceedings, PD Research Symposium	2002, 2003	4a, 1b	3.3
22	Bextine, Blua, Miller	A quantitative real-time PCR protocol and novel DNA extraction technique to detect *Xf* in GWSS.	(in preparation, for J. Econ. Entomol.)		1	3.3
23	Bextine, Lauzon, Potter, Lampe, Miller	Delivery of a genetically marked *Alcaligenes* sp. to GWSS for use in a paratransgenic control strategy.	Current Microbiol. 48(5): 327-331.	2004	3b	5.1
24	Bextine, Miller	Comparison of whole-tissue and xylem fluid collection techniques to detect *Xf* in grapevine and oleander.	Plant Disease 88: 600-604.	2004	1a	3.2, 3.3
25	Bextine, Miller	Environmental fate of a genetically marked endophyte in grapevines and GWSS.	Proceedings, PD Research Symposium	2003	1a, 3b	5.2
26	Bextine, Miller	Improved detection of *Xf* in asymptomatic grapevine using xylem fluid collection technique.	Phytopathology 93S: 8.	2003	1a	3.2, 3.3
27	Bextine, Miller	Insect-symbiotic bacteria inhibitory to *Xf* in sharpshooters: pressure bomb extraction of xylem fluid to improve bacterial detection of *Xylella* in plants.	Proceedings, PD Research Symposium	2002	1a, 3b	5.2
28	Bextine, Miller	Paratransgenesis to control PD: biology of endophytic bacteria in grape plants and bioassay of reagents to disrupt PD.	Proceedings, PD Research Symposium	2003	1a, 3b	5.2
29	Bextine, Miller	Pressure chamber extraction of xylem fluid: improving bacterial detection in plants affected by *Xf*.	Proceedings, PD Research Symposium	2003	1a, 3b	5.2
30	Bextine, Tuan, Shaikh, Blua, Miller	Evaluation of methods for extracting *Xf* DNA from GWSS.	J. Econ. Entomol. 97(3): 757-763.	2004	1b	3.2, 3.3
31	Blackmer, Castle, Hagler, Naranjo, Toscano	Sampling, seasonal abundance, and comparative dispersal of GWSS in citrus and grapes.	Proceedings, PD Research Symposium	2001	1b	2.1
32	Blackmer, Hagler, Simmons	Sampling, seasonal abundance, and comparative dispersal of GWSS in citrus and grapes: dispersal progress report.	Proceedings, PD Research Symposium	2002, 2003	1b	2.1

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Line Number	Principal Investigators	Title	Citation	Year	Research Categories	
					NAS	AVF
33	Blackmer, Hagler, Simmons, Canas	Comparative dispersal of *Homalodisca coagulata* and *Homalodisca liturata.*	Environ. Entomol. 33(1): 88-99.	2004	1b	2.2
34	Blua, Bextine, Redak	Developing a method to detect Xf in GWSS.	Proceedings, PD Research Symposium	2002, 2003	1a, 1c	3.2
35	Blua, Miller	Quantitative aspects of the transmission of *Xf* by GWSS.			1a, 1c	3.3
36	Blua, Morgan	Dispersion of *Homalodisca coagulata* , a vector of *Xf* , into vineyards in southern California.	J. Econ. Entomol. 96(5): 1369-1374.	2003	1b	2.2
37	Blua, Redak	Impact of a screen barrier on the introgression of GWSS into a nursery yard.	Proceedings, PD Research Symposium	2003	1b	5.5
38	Blua, Redak	Impact of sub-lethal doses of neonicotinoids on GWSS feeding and transmission of PD.	Proceedings, PD Research Symposium	2001, 2002	5a, 5b	3.3, 5.3
39	Blua, Redak, Bethke, Morgan	Impact of selected insecticides on mortality and feeding of *Homalodisca coagulata* , a vector of *Xf* .	(in preparation)		5a, 5b	5.3
40	Blua, Redak, Coviella, Akey	Relationship between total population counts of GWSS and numbers obtained from various sampling methods.	Proceedings, PD Research Symposium	2002, 2003	1b	4.1
41	Boucias, Mizell	Manipulation of *Hirsutella* as a biological control of GWSS.			3a	5.1
42	Bourne, Lu, Ren	Genetic analysis of grapevine resistance to Pierce's disease and anthracnose through screening the F1 progeny of N18-6 X cabernet sauvignon.	Proc. Florida State Hort. Soc. 116 (in press)		2a	5.6
43	Brlansky	Transmission of the citrus variegated chlorosis bacterium, *Xf* , with the GWSS.			1a	3.2, 3.3
44	Brodbeck, Andersen, Mizell	A comparison of glabrous and pubescent soybean lines for their effects on the developmental biology of a xylophagous leafhopper.	Environ. Entomol. (in press)		3a	5.1, 2.2
45	Brodbeck, Andersen, Mizell, Oden	Comparative nutrition and developmental biology of xylem-feeding leafhoppers reared on four genotypes of *Glycine max* .	Environ. Entomol. 33(2): 165-173.	2004	3a	2.2, 2.1
46	Bruening	Roles of *Xf* proteins in virulence.	Proceedings, PD Research Symposium	2003	1a	3.1
47	Bruening	Virulence analysis of the PD agent *Xf* .	Proceedings, PD Research Symposium	2001, 2002	1a	3.1
48	Bruening, Civerolo	Exploiting *Xf* proteins for PD control.			1a	3.1
49	Burks, Redak	The identify and reinstatement of *Homalodisca liturata* Ball and *Phera lacerta* Fowler.	Proc. Entomol. Soc. Wash. 105: 674-678.	2003	1b	2.1
50	Buzkan, et al.	Improvements in sample preparation and polymerase chain reaction techniques for detection of *Xf* in grapevine tissue.	Amer. J. Enol. Viticulture 54(4): 307-312.	2003	1	3.1, 3.3

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Line Number	Principal Investigators	Title	Citation	Year	Research Categories	
					NAS	AVF
51	Byrne, Mello, Toscano	Biochemical monitoring of acetylcholinesterase sensitivity to organophosphorus insecticides in GWSS and smoke-tree sharpshooter.	J. Econ. Entomol. 96(6): 1849-1854.	2003	5b	5.3
52	Byrne, Toscano	Characterization of plant metabolites of imidacloprid in citrus trees and grapevines, and evaluation of their efficacy against GWSS.	Proceedings, PD Research Symposium	2003	5b	5.3
53	Byrne, Toscano, Federici	Evaluation of resistance potential in GWSS using toxicological, biochemical, and genomics approaches.			2a, 2b	5.6
54	Campanharo, Lemos, Lemos	Growth optimization procedures for the phytopathogen *Xf*.	Current Microbiol. 46: 99-102.	2003	1a	3.3
55	Castle	Monitoring the seasonal incidence of *Xf* in GWSS populations.			1b	2.2
56	Castle, Naranjo, Toscano	Sampling, seasonal abundance, and comparative dispersal of GWSS in citrus and grapes: sampling progress report.	Proceedings, PD Research Symposium	2002, 2003	1b	4.1
57	Chen	Developing a microarray-PCR-based identification and detection system for Xf strains important to California.	Proceedings, PD Research Symposium	2003	1a	4.2
58	Chen, et al.	Characterization of a *Xf* field strain on the genomics basis.	Phytopathology 93S: 16.	2003	1a	3.1
59	Chen, Leopold, Ruud, Harris	Effect of selected plants on the feeding and oviposition of GWSS.	(submitted to Ann. Entomol. Soc. Amer.)		1b	2.2
60	Ciapina, Alves, Lemos	A nested-PCR assay for detection of Xf in citrus plants and sharpshooter leafhoppers.	J. Appl. Microbiol. 96: 546-551.	2004	1a	2.2, 3.2
61	Civerolo	Epidemiology of *Xf* diseases in California.	Proceedings, PD Research Symposium	2001	1a	3.3
62	Civerolo	Genome sequence of a strain of *Xf* associated with PD in California.	Proceedings, PD Research Symposium	2001	1a	3.1
63	Civerolo	Sequence of the genome of *Xf* causing PD in California.	Proceedings, PD Research Symposium	2002	1a	3.1
64	Cohen	Development of an artificial diet for GWSS.	Proceedings, PD Research Symposium	2001, 2002	3a	5.1
65	Cokl, Virant-Doberlet	Communication with substrate-borne signals in small plant-dwelling insects.	Annual Review Entomol. 48: 29-50.	2003	1b	2.1
66	Coletta-Filho, Machado	Geographical genetic structure of *Xf* from citrus in Sao Paulo State, Brazil.	Phytopathology 93(1): 28-34.	2003	1a	3.1, 3.3
67	Cook, Goes da Silva, Lim, Kim	Functional genomics of the grape-X*ylella* interaction: towards the identification of host resistance determinants.	Proceedings, PD Research Symposium	2001, 2002, 2003	1a, 1c, 2b	3.1, 3.2, 5.6
68	Cooksey	Biological control of PD with non-pathogenic strains of *Xf.*	Proceedings, PD Research Symposium	2001, 2002, 2003	3b	5.2

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Line Number	Principal Investigators	Title	Citation	Year	Research Categories	
					NAS	AVF
69	Cooksey	Control of PD through degradation of xanthan gum.	Proceedings, PD Research Symposium	2001, 2002, 2003	3b	5.2
70	Cooksey	DNA microarray and mutational analysis to identify virulence genes in *Xf*.	Proceedings, PD Research Symposium	2003	1a	3.1
71	Cooksey, Borneman	Culture independent analysis of endophytic microbial communities in grapevine in relation to PD.	Proceedings, PD Research Symposium	2003	3b	5.2
72	Cooksey, Costa	Epidemiology of PD in southern California: identifying inoculum sources and transmission pathways.	Proceedings, PD Research Symposium	2001, 2002, 2003	1a	3.3
73	Cooksey, Miller	Insect-symbiotic bacteria inhibitory to *Xf* in sharpshooters: toxic peptides against *Xylella* .	Proceedings, PD Research Symposium	2003	3b	5.2
74	Costa	Micro-reader for analysis of plant tissue for the presence of *Xf* .			1a	3.3
75	Costa, Cooksey	Effects of feeding substrate on retention and transmission of Xf strains by GWSS.	Proceedings, PD Research Symposium	2003	1a	3.3
76	Costa, Cooksey	Incidence of *Xf* in GWSS populations and the impact of multiple-strain infections of *Xf* on acquisition and transmission.			1b	3.2, 3.3
77	Costa, Cooksey, Gispert	Impact of multiple strain infections of *Xf* on acquisition and transmission by GWSS.	Proceedings, PD Research Symposium	2001, 2003	1a	3.3
78	Costa, Raetz, Pickard, Gispert, Hernandez-Martinez, Dumenyo, Cooksey	Plant hosts of *Xf* in and near southern California vineyards.	(in preparation)		1a	3.2
79	Coudron, Goodman	Development of an artificial diet and evaluation of artificial ovipositional substrates for the in vitro rearing of *Gonatocerus* spp., parasitoids of GWSS.			3a	5.1
80	Coudron, Goodman	Development of an artificial diet for GWSS.			3a	5.1
81	Cousins	Rootstock influence on PD.			1c	5.5, 3.3
82	Cousins, Lu	Rootstock variety influence on PD symptoms in grafted Chardonnay (*Vitis vinifera L.*) grapevines.	Proceedings, PD Research Symposium	2001, 2002	1c	5.5, 3.3
83	Cousins, Lu	Rootstock variety influence on PD symptoms in grafted Chardonnay and Cabernet Sauvignon (*Vitis vinifera L.*) grapevines.	Proceedings, PD Research Symposium	2003	1c	5.5, 3.3
84	Coviella, Luck	GWSS population dynamics as a tool for eradicating GWSS populations.	Proceedings, PD Research Symposium	2003	1c	5.5
85	Daane	Importance of ground vegetation in the dispersion and overwintering of *Xf* .			4a	4.1, 5.1

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Line Number	Principal Investigators	Title	Citation	Year	Research Categories	
					NAS	AVF
86	Daane, Johnson	Biology and ecology of GWSS in the San Joaquin Valley.	Proceedings, PD Research Symposium	2002, 2003	1b	2.1
87	Daane, Purcell, Winstrom	Effects of group, variety and climate on the establishment and persistence of *Xf* infections causing almond leaf scorch.			1a	2.2
88	Dahlsten	Effects on vertebrates of riparian woodland management for control of PD.	Proceedings, PD Research Symposium	2001	4a	5.5
89	Damsteegt, et al.	GWSS transmission of *Xf*, causal agent of citrus variegated chlorosis.	Phytopathology 93S: 19.	2003	1b	3.2, 3.3
90	Dandekar, Gupta, Hong-Geller, McDonald	Design of chimeric antimicrobial proteins for rapid clearance of *Xylella.*	Proceedings, PD Research Symposium	2003	3b	5.2
91	Darjean-Jones	Chemical and biological strategies for the management of *Xf*, causal agent of PD of grapevines.	PhD dissertation, UC Davis.	2004	3, 5	5.2, 5.4
92	Da-Silva	Hidden Markov models applied to a subsequence of the *Xf* genome.	Genetics & Molecular Biology 26(4): 529-535.	2003	1a	3.1
93	de Assis, et al.	Gas exchanges and carbohydrate metabolism in orange trees with citrus variegated chlorosis.	Brazilian Journal Plant Physiology 15(1): 25-31.	2003	1a	3.1, 3.2
94	de Leon	Population genetic structure of GWSS determined by ISSR-PCR DNA fingerprinting.	Proceedings, PD Research Symposium	2003	1b	2.1
95	de Leon, Jones	Detection of DNA polymorphisms in GWSS by PCR-based DNA fingerprinting methods.	Proceedings, PD Research Symposium	2002	1b	2.1
96	de Leon, Jones	Detection of DNA polymorphisms in *Homalodisca coagulata* by PCR-based DNA fingerprinting methods.	Annals Entomol. Soc. America 97(3): 574-585.	2004	1b	2.1
97	de Leon, Jones, Morgan	Population genetic structure of *Homalodisca coagulata*, the vector of the bacterium *Xf* causing Pierce's disease in grapevines.	Annals Entomol. Soc. America 97(4): 809-818.	2004	1b	2.1
98	de Oliveira, et al.	Crystallization and preliminary X-ray diffraction analysis of an oxidized state of Ohr from *Xf*.	Acta Crystallographica Section D-Biological Crystallography 60(Part 2): 337-339.	2004	1a	3.1
99	de Souza, et al.	Analysis of gene expression in two growth states of *Xf* and its relationship with pathogenicity.	Molecular Plant-Microbe Interactions 16(10): 867-875.	2003	1a	3.1
100	Dumenyo, et al.	Site-directed mutagenesis of specific genes in a Pierce's disease strain of *Xf*.	Abstracts of the General Meeting of the American Society for Microbiology: H-147.	2003	1a, 3b	3.1
101	Facincani, Ferro, Pizauro, Pereira, Lemos, Prado, Ferro	Carbohydrate metabolism of Xf: Detection of glycolytic and pentose phosphate pathway enzymes and cloning and expression of the enolase gene.	Genetics Molecular Biology 26(2): 203-211.	2003	1a	3.1
102	Fatmi, et al.	A combined agar absorbent and BIO-PCR assay for rapid, sensitive detection of *Xf* in grape and citrus.	Phytopathology 93(6 Supplement): S25.	2003	1a	3.3

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Line Number	Principal Investigators	Title	Citation	Year	Research Categories	
					NAS	AVF
103	Federici	Development of GWSS mimetic insecticidal peptides, and an endophytic bacterial system for their delivery to mature grape.	Proceedings, PD Research Symposium	2003	3b	5.1, 5.2
104	Francis, Civerolo, Lin	Real-time PCR for clinical detection and differentiation of *Xf* strains.	Proceedings, PD Research Symposium	2003	1a	3.3
105	Freeman	Ultrastructural contributions to the study of GWSS and PD.	Proceedings, PD Research Symposium	2002, 2003	1b	2.1
106	Gabriel	Complementation vector with increased stability in *Xylella*.			1a	3.1
107	Gabriel	Role of type I secretion in PD.	Proceedings, PD Research Symposium	2002, 2003	1a	3.1, 3.3
108	Gilchrist, Cook, Lincoln	Isolation and functional testing of PD-specific promoters from grape.			1a	3.1, 5.2
109	Gilchrist, Lincoln	Rapid screening of grape cDNA libraries and functional testing of genes conferring resistance to PD.	Proceedings, PD Research Symposium	2003	1a	3.1, 5.2
110	Gilchrist, Lincoln, Bruening, Walker	Application of *Agrobacterium rhizogenes*-mediated transformation strategies for (a) rapid high through put screen for genetic resistance to PD in grape that maintains the clonal integrity of the recipient host, and (b) rapid screening for virulence determinants in *Xf*.	Proceedings, PD Research Symposium	2001, 2002	1a	3.1, 3.2, 5.2
111	Gomes, et al.	Abscisic acid and indole-3-acetic acid contents in orange trees infected by *Xf* and submitted to cycles of water stress.	Plant Growth Regulation 39(3): 263-270.	2003	1a	3.1, 3.3
112	Grafton-Cardwell	Efficacy of insecticides used for GWSS control in citrus nursery stock.	Proceedings, PD Research Symposium	2002	5b	5.3
113	Grafton-Cardwell	Evaluation of efficacy of Sevin treatments in the Porterville GWSS infestation.	Proceedings, PD Research Symposium	2001	5b	5.3
114	Grafton-Cardwell	Screening insecticides in nursery citrus for efficacy against GWSS.			5b	5.3
115	Grafton-Cardwell, Kallsen	Efficacy of insecticides used for GWSS control in citrus.	Proceedings, PD Research Symposium	2001	5b	5.3
116	Granett, Walker, Omer	Prevention of PD transmission and infection: role of induced plant resistance.			1b, 2a	5.6
117	Groves & Chen	Epidemiology of PD in the central San Joaquin Valley of California: factors affecting pathogen distribution and movement.	Proceedings, PD Research Symposium	2003	1a	3.3
118	Guilhabert, Kirkpatrick	Characterization of putative rolling-circle plasmids from the gram-negative bacterium *Xf* and their use as shuttle vectors.	(submitted to Plasmid)	2004	3b, 1a	5.2, 3.1
119	Habermann, et al.	CO2 assimilation, photosynthetic light response curves, and water relations of 'Pera' sweet orange plants infected with *Xf*.	Brazilian Journal of Plant Physiology 15(2): 79-87.	2003	1a	3.3, 3.2

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					NAS	AVF
120	Habermann, et al.	Gas exchange rates at different vapor pressure deficits and water relations of 'Pera' sweet orange plants with citrus variegated chlorosis (CVC).	Scientia Horticulturae (Amsterdam) 98(3): 233-245.	2003	1a	3.3, 3.2
121	Hagler, Blackmer, Daane, Groves	Quantifying landscape-scale movement patterns of GWSS and its natural enemies using a novel mark-capture technique.			1b	5.1
122	Hagler, Daane, Costa	A monoclonal antibody specific to GWSS egg protein: a tool for predator gut analysis and early detection of pest infestation.	Proceedings, PD Research Symposium	2001, 2002, 2003	1b	5.1
123	Hagler, Daane, Groves, Henneberry	An immunological approach for quantifying predation rates on GWSS.			1b	5.1
124	Hagler, Henneberry, Daane, Fournier, de Leon, Groves, Civerolo	Identifying key predators of the various GWSS lifestages.			1b	5.1
125	Hammock, Kamita	Isolation and characterization of GWSS pathogenic viruses.	Proceedings, PD Research Symposium	2001	1b	5.1
126	Hashim	Monitoring and control measures for PD in Kern County.	Proceedings, PD Research Symposium	2002	1a, 1c	3.3, 4.3
127	Hashim, Hill	Monitoring and control measures for PD in Kern County, and epidemiological assessments of PD.	Proceedings, PD Research Symposium	2003	1a, 1c	3.3, 4.3
128	Henneberger, et al.	Effect of low temperature on populations of *Xf* in naturally infected sycamore.	Phytopathology 93S(6): 34-35.	2003	1a	3.2, 3.3
129	Hill	Epidemiological assessments of PD.			1a, 1c	3.3
130	Hill, Hashim	The epidemiology of PD.	Proceedings, PD Research Symposium	2002	1a, 1c	3.3
131	Hix	Development of trapping systems to trap GWSS adults and nymphs in grape.	Proceedings, PD Research Symposium	2001, 2002, 2003	1b	4.1
132	Hix	GWSS impact on orange yield, fruit size, and quality.	Proceedings, PD Research Symposium	2002, 2003	1	2.2, 6.0
133	Hix, Toscano, Gispert	Area-wide management of GWSS in the Temecula and Coachella valleys.	Proceedings, PD Research Symposium	2003	1	5.1, 5.5
134	Hix, Toscano, Redak, Blua	Area-wide management of GWSS in the Temecula Valley.	Proceedings, PD Research Symposium	2001, 2002	1	5.1, 5.5
135	Hoch, Burr	Evaluating the roles of pili in twitching and long distance movement of Xf in grape xylem and in the colonization of sharpshooter foregut.			1	3.2
136	Hoch, Burr	Understanding *Xf* colonization and communication in xylem lumina.	Proceedings, PD Research Symposium	2002, 2003	1	3.2
137	Hoddle	Biocontrol of GWSS in California: one cornerstone for the foundation of an IPM program.			3a	5.1

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Line Number	Principal Investigators	Title	Citation	Year	Research Categories	
					NAS	AVF
138	Hoddle	Interspecific competition between *Gonatocerus ashmeadi* and *G. triguttatus* for GWSS egg masses.	Proceedings, PD Research Symposium	2002	3a	5.1
139	Hoddle	Interspecific competition between *Gonatocerus ashmeadi, G. triguttatus,* and *G. fasciatus* for GWSS egg masses.	Proceedings, PD Research Symposium	2003	3a	5.1
140	Hoddle	Investigating the behavior and biology of exotic mymarid parasitoids released for GWSS control, and evaluating techniques for enhancement in the field.	Proceedings, PD Research Symposium	2003	3a	5.1
141	Hoddle	Searching for and collecting egg parasitoids of GWSS and other *Homalodisca* species in southeastern and southwestern Mexico.			3a	5.1
142	Hoddle	The potential adventive geographic range of GWSS, and the grape pathogen *Xf*: implications for California and other grape growing regions of the world.	Crop Protection 23(8): 691-699.	2004	1a	2.2, 3.3
143	Hoddle, Luck	Realized lifetime parasitism and the influence of brochosomes on field parasitism rates of GWSS egg masses by *Gonatocerus ashmeadi* .			3a	5.1
144	Hoddle, Stouthamer	Is the GWSS parasitoid *Gonatocerus ashmeadi* one species or a complex of morphologically indistinguishable sibling species?	Proceedings, PD Research Symposium	2002, 2003	3a	5.1
145	Hoddle, Triapitsyn	Searching for and collecting egg parasitoids of GWSS in the central and eastern USA.	Proceedings, PD Research Symposium	2003	3a	5.1
146	Hoddle, Triapitsyn, Morgan	Distribution and plant association records for *Homalodisca coagulata* in Florida.	Florida Entomol. 86(1): 89-91.	2003	1b	2.2
147	Hoddle, Triapitsyn, Phillips	Survey of egg parasitoids of GWSS in California.	Proceedings, PD Research Symposium	2001	3a	5.1
148	Huang, et al.	Association of *Xf* with leaf scorch in Japanese beech bonsai.	Canadian J. Plant Pathology-Revue Canadienne de Phytopathologie 25(4): 401-405.	2003	1a	3.2, 3.3
149	Huang, Sherald	Isolation and phylogenetic analysis of *Xf* from its invasive alternative host, porcelain berry.	Current Microbiology 48(1): 73-76.	2004	1a	3.2, 3.3
150	Hunt	Mating behavior of GWSS.	Proceedings, PD Research Symposium	2001, 2002	1	2.1
151	Hunter, Dang	Identifying genetic targets for GWSS control: available genetic datasets for GWSS.	Proceedings, PD Research Symposium	2003	3	5.1
152	Hunter, Dang, Backus, Habibi, Morgan	Understanding GWSS feeding: gene expression in GWSS salivary glands and midguts.	Proceedings, PD Research Symposium	2003	1b	2.1
153	Hunter, Dang, Tipping, Mizell	Expanding the genetic targets for sharpshooter control: genetic datasets for sharpshooters that transmit PD.	Proceedings, PD Research Symposium	2003	1b	3.1, 2.2
154	Igo	Isolation of bacteriophages specific for *Xf*.			3b	5.2

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Line Number	Principal Investigators	Title	Citation	Year	Research Categories	
					NAS	AVF
155	Igo	The *Xf* cell surface.	Proceedings, PD Research Symposium	2002, 2003	3b	5.2
156	Irvin, Hoddle	Egg age preference and "window of susceptibility" of GWSS eggs to attack by *Gonatocerus ashmeadi* and *G. triguttatus* .	Proceedings, PD Research Symposium	2001	3a	5.1
157	Jain, Basha	A capillary electrophoretic method for isolation and characterization of grape xylem proteins.	African Journal of Biotechnology 2(3): http://www.bioline.org.br/request?jb03013	2003	1, 3b, 2a	3.2
158	Johnson, Daane, Groves, Backus	Overwintering biology of GWSS in California's San Joaquin Valley: factors limiting vector movement and distribution.			1	2.2
159	Jones	Biological control of GWSS.	Proceedings, PD Research Symposium	2002	3a	5.1
160	Jones	Brochosomes: A novel defense mechanism deterring egg parasitism of GWSS.	J. Insect Science (Tucson) 3(33 Cited October 24, 2003): 13.	2003	2a	2.2, 5.2
161	Jones	Classical biological control of GWSS.	Proceedings, PD Research Symposium	2001	3a	5.1
162	Kamita, Hammock	Development of peptide antibiotic-based control strategies for *Xf*.	Proceedings, PD Research Symposium	2003	3a	5.2
163	Kamita, Hammock	Evaluation of an antibacterial peptide (cercopin A) as a resistance agent in plant xylem against *Xf*.			3b	5.6
164	Kanga, Jones, Humber, Boyd	Fungal pathogens of GWSS.	Florida Entomol. 87(2): 225-228.	2004	3a	5.2
165	Kaya	Entomopathogenic fungi for biological control of GWSS.	Proceedings, PD Research Symposium	2003	3a	5.2
166	Kaya, McGuire	A new entomopathogenic fungus, *Pseudogibellula formicarum* , for the biological control of GWSS.			3a	5.2
167	Kelly	Spatial database creation and maintenance for PD/GWSS in California.			1	4.1, 4.2
168	Kirkpatrick	Analysis of *Xf* transposon mutants and development of an in planta *Xf* plasmid vector.	Proceedings, PD Research Symposium	2003	1a	5.2, 3.1
169	Kirkpatrick	Characterize and assess the biocontrol potential of bacterial endophytes of grapevines in California.	Proceedings, PD Research Symposium	2003	3b	5.2
170	Kirkpatrick	Evaluation of bactericides and modes of delivery for managing PD.	Proceedings, PD Research Symposium	2003	3b	5.2
171	Kirkpatrick	Evaluation of bactericides for control of PD and analysis of *Xf* transposon mutants.			3b	5.2
172	Kirkpatrick	Identification of mechanisms mediating cold therapy of *Xf*-infected grapevines.			3	5.6, 5.2

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					NAS	AVF
173	Kirkpatrick	Production and screening of *Xf* transposon mutants and microscopic examination of *Xf*-resistant and susceptible *Vitis* germplasm.			3b	5.2
174	Kirkpatrick	Production and screening of *Xf* transposon pathogenicity and attachment mutants.			3b	5.2
175	Kirkpatrick	Studies on bacterial canker and almond leaf scorch.			3	3.2, 5.2
176	Kirkpatrick, Guilhabert	Biological, cultural, genetic, and chemical control of PD: production and screening of *Xf* transposon pathogenicity and attachment mutants.	Proceedings, PD Research Symposium	2002	3b, 5b	5.2, 5.5, 5.3
177	Kirkpatrick, Weber, Andersen, Purcell, Walker	Biological, cultural, and chemical management of PD.	Proceedings, PD Research Symposium	2001	3b, 5b	5.2, 5.5, 5.3
178	Kirkpatrick, Whistler	Evaluation of grapevine endophytic bacteria for control of PD, and development of in planta *Xf* plasmid vector.			3b	5.2
179	Koide, Neto, Gomes, Marques	Insertional transposon mutagenesis in the *Xf* citrus variegated chlorosis strain with transposome.	Current Microbiol. 48(4): 247-250.	2004	3b	3.1
180	Labavitch, Backus, Morgan	The contribution of the pectin-degrading enzyme polygalacturonase (PG) in transmission of *Xf* to grape and use of PG-inhibitor proteins for transgenic resistance to PD.			1c, 2b, 3b	3.1, 3.2, 5.2
181	Labavitch, Matthews, Backus, Shackel	Linking the model of the development of PD in grapevines to an understanding of the dynamics of GWSS transmission of *Xf* to grapevines and grapevine gene expression markers of PD infection.			1c, 2b, 3b	3.1, 3.2, 5.2
182	Labavitch, Matthews, Rost	The development of PD in xylem: the roles of vessel cavitation, cell wall metabolism, and vessel occlusion.	Proceedings, PD Research Symposium	2001, 2002, 2003	1a	3.2
183	Lampe, Miller	Paratransgenesis for control of PD: manipulation of endophytic bacteria for paratransgenic control of PD.	Proceedings, PD Research Symposium	2002	3b	5.2
184	Lampe, Miller	Paratransgenesis to control PD: isolation and analysis of anti-*Xylella* single chain antibodies.	Proceedings, PD Research Symposium	2003	3b	5.2
185	Lauziere, Ciomperlik, Wendel	Biological control of GWSS in Kern County, California.	Proceedings, PD Research Symposium	2002	3a	5.1
186	Lauzon	A survey of insect vectors of PD and PD-infected plants for the presence of bacteriophages that infect *Xf*.	Proceedings, PD Research Symposium	2001	1, 3b	5.1, 5.2
187	Lauzon, Miller	Insect-symbiotic bacteria inhibitory to *Xf* (paratransgenesis for control of PD): identification of endophytic bacteria cycled by GWSS to host plants.	Proceedings, PD Research Symposium	2002	1, 3b	5.1, 5.2
188	Lauzon, Miller	Paratransgenesis to control PD: the "social life" of *Alcaligenes xylosoxidans denitrificans* .	Proceedings, PD Research Symposium	2003	1, 3b	5.2
189	Leal, Zalom	Developing a novel detection and monitoring system for GWSS.	Proceedings, PD Research Symposium	2001	1	4.1

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Line Number	Principal Investigators	Title	Citation	Year	Research Categories	
					NAS	AVF
190	Leite, Andersen, Ishida	Colony aggregation and biofilm formation in xylem chemistry-based media for *Xf*.	FEMS Microbiology Letters 230(2): 283-290.	2004	1a	3.2
191	Leite, et al.	Nutritional effects on colony size and biofilm formation of *Xf* growing on simple chemically-defined media.	Phytopathology 93S(6S): 50.	2003	1a	3.2
192	Leite, Ishida, Andersen	Effect of hydrophobicity and divalent ions on biofilm formation of *Xf*.	Phytopathology 93S(6): 50.	2003	1a	3.2
193	Lemos, Alves, Campanharo	Genomics-based design of defined growth media for the plant pathogen *Xf*.	FEMS Microbiol. Lett. 219: 39-45.	2003	1a	3.1
194	Leopold	A preliminary study on parasitism of GWSS egg masses by *Gonatocerus ashmeadi* and *G. triguttatus*.	Proceedings, PD Research Symposium	2003	3a	5.1
195	Leopold, Freeman, Buckner, Nelson	Mouthpart morphology and stylet penetration of host plants by the GWSS.	Arthropod Structure & Development 32(2-3): 189-199.	2003	1b	2.2
196	Leopold, Yocum	Cold storage of parasitized and unparasitized eggs of GWSS.	Proceedings, PD Research Symposium	2001, 2003	3a	5.1
197	Leopold, Yocum	Host selection and low temperature storage of GWSS.	Proceedings, PD Research Symposium	2002	3a	5.1
198	Li, et al.	Rapid identification of insertion sites of green florescent protein: Labeled mutants of *Xf*.	Abstracts of the General Meeting of the American Society for Microbiology: H-146.	2003	3b	3.1, 3.3
199	Li, Gray	Effect of five antimicrobial peptides on the growth of *Agrobacterium tumefaciens*, *Escherichia coli* and *Xylella fastidiosa*.	Vitis 42(2): 95-97.	2003	3b	5.2
200	Li, Hartung	Labeled and defined mutants of *Xf* by triparental matings.	Phytopathology 93S(6S): 51.	2003	3b	3.1, 3.2
201	Li, Pria, Lacava, Hartung	Presence of Xf in sweet orange fruit and seeds and its transmission to seedlings.	Phytopath. 93(8): 953-958.	2003	1a	3.3
202	Li, Zhou, Pria, Teixeira, Miranda, Pereira, Ayres, He, Costa, Hartung	Citrus and coffee strains of *Xf* induce PD in grapevine.	Proceedings, PD Research Symposium	2002	1a	3.3, 3.2
203	Lin	Characterization and identification of PD resistance mechanisms: analysis of xylem anatomical structures and of natural products in xylem sap among *Vitis*.	Proceedings, PD Research Symposium	2003	2a	5.6, 3.2
204	Lin	Developing transcriptional profiles and microarray expression analysis of grape plant response to *Xf*.	Proceedings, PD Research Symposium	2003	2a	3.2
205	Lin, Walker	Developing gene expression profiles for research on grape responses to *Xf*.	American Journal of Enology & Viticulture 54(3): 228A.	2003	1a	3.2, 3.1
206	Lin, Walker	Development of SSR markers for genotyping and genetic diversity assessment of *Xf* in California.			1a, 2a	3.1, 3.2, 3.3

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					NAS	AVF
207	Lindow	Characterization of fimbriae production and attachment of FIMA- and FIMF- mutants of *Xf* in vitro.	Proceedings, PD Research Symposium	2002	3b, 1a	5.2, 3.1, 5.6
208	Lindow	Differential plant-inducibility of putative virulence genes by *Xf* in susceptible and resistant plant hosts.	Proceedings, PD Research Symposium	2003	3b, 1a	3.1, 5.6, 5.2
209	Lindow	Identification of traits of *Xf* conferring virulence to grape and insect transmission by analysis of global gene expression using DNA microarrays.			3b, 1a	3.1, 5.6, 3.2
210	Lindow	Management of PD of grape by interfering with cell-cell communication in *Xf.*	Proceedings, PD Research Symposium	2002, 2003	3b, 1a	5.6, 5.2
211	Lindow	Role of attachment of *Xf* to grape and insects in its virulence and transmissibility.	Proceedings, PD Research Symposium	2003	1a	3.2, 5.2, 3.3
212	Lindow	Role of *Xf* attachment on pathogenicity.	Proceedings, PD Research Symposium	2001	1a	3.2, 5.2
213	Lindow	The role of cell-cell signaling in host colonization by *Xf.*	Proceedings, PD Research Symposium	2001	1a	3.3
214	Lindow, Richardson	Determination of genes conferring host specificity in grape strains of Xf using whole-genomic DNA microarrays.	Proceedings, PD Research Symposium	2003	1a, 2a	3.3, 3.1
215	Logarzo, Triapitsyn, Jones	New host records for two species of *Gonatocerus* egg parasitoids of proconiine sharpshooters in Peru.	Florida Entomol. 86(4): 486-487.	2003	3a	5.2
216	Lopes, et al.	Weeds as alternative hosts of the citrus, coffee, and plum strains of *Xf* in Brazil.	Plant Disease 87.	2003	4a	3.3
217	Lopez, Mizell, Andersen, Brodbeck	Overwintering biology, food supplementation, and parasitism of eggs of *Homalodisca coagulata* by *Gonatocerus ashmeadi* and *G. morrilli*.	J. Entomol. Sci. 39(2): 214-222.	2004	3a	5.1
218	Lu	Host plant resistance to GWSS in grapes.	Proceedings, PD Research Symposium	2002	2a	2.2, 5.6
219	Lu, Ren, Cousins	Field evaluation of grape rootstock response to natural infection by PD.	Proceedings, PD Research Symposium	2003	2a	5.6
220	Luck, Coviella, Morgan	Evaluation of olfactory responses by *Gonatocerus ashmeadi*, a parasitoid of GWSS egg masses on various plants.	Proceedings, PD Research Symposium	2003	3a	5.1
221	Luck, Hoddle	Spatial and temporal relations between GWSS survival and movement, xylem flux patterns, and xylem chemistry in different host plants.	Proceedings, PD Research Symposium	2001, 2002, 2003	1b	2.2
222	Luck, Redak	Seasonal changes in GWSS age structure, abundance, host plant use, and dispersal.	Proceedings, PD Research Symposium	2001, 2002	1b	2.2, 3.1
223	Luck, Stouthamer, Cooksey, Nunney	Multilocus sequence typing to identify reservoirs of *Xf* diversity in natural hosts in California.			1a	3.3
224	Luvisi	Elevation's effect on survival of GWSS in Kern County.	Proceedings, PD Research Symposium	2001	1b	2.1

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					NAS	AVF
225	Luvisi, Wendel	Kern County Pilot Project.			1	4.1
226	Marucci, Giustolin, Miranda, Miquelote, Almeida, Lopes	Selection of a non-host plant of *Xf* for rearing healthy sharpshooter vectors.	Scientia Agricola 60: 669-675.	2003	3a	2.2, 5.1
227	Matthews	Physiological factors and consequences of systemic infection by *Xf*.			1a	3.2
228	McElrone, et al.	Interactive effects of water stress and xylem-limited bacterial infection on the water relations of a host vine.	J. Experimental Botany 54(381): 419-430.	2003	1a	3.2
229	McElrone, Forseth	Photosynthetic responses of a temperate liana to *Xf* infection and water stress.	J. Phytopathology-Phytopathologische Zeitschrift 152(1): 9-20.	2004	1a	3.2
230	McKamey	Developing a stable classification of the GWSS genus *Homalodisca*.	Proceedings, PD Research Symposium	2002, 2003	1b	2.1
231	Meredith, Dandekar	Directing potential anti-*Xylella* gene products to the xylem of transgenic grapevines.	Proceedings, PD Research Symposium	2002, 2003	2b	5.6, 5.2
232	Meredith, Dandekar	Genetic transformation to improve the PD resistance of existing grape varieties.	Proceedings, PD Research Symposium	2001	2b	5.6, 5.2
233	Miller, Cooksey, Lauzon, Lampe, Peloquin	Insect-symbiotic bacteria inhibitory to *Xf* in sharpshooters.	Proceedings, PD Research Symposium	2001	3b	3.2, 5.1
234	Mizell, Andersen	Behavioral and physiological determinants of the geographical range of GWSS.	Proceedings, PD Research Symposium	2003	1b	2.2, 2.1
235	Mizell, Andersen	Effects of juvenile hormone analogs on survival and reproductive status of GWSS.			1b, 3a	2.1, 5.1
236	Mizell, Andersen	Host selection behavior and improved detection for GWSS.	Proceedings, PD Research Symposium	2001	1b, 3a	2.2, 4.1
237	Mizell, Andersen	Keys to management of GWSS: interactions between host plants, malnutrition, and natural enemies.	Proceedings, PD Research Symposium	2001, 2002, 2003	1b, 3a	5.1, 2.2
238	Mizell, Andersen, Oevering, Phillips	Population dynamics and interactions between GWSS and its host plants in response to California phenology.	Proceedings, PD Research Symposium	2003	1b	2.2, 4.1
239	Mizell, Boucias	Mycopathogens and their exotoxins infecting GWSS: survey, evaluation, and storage.	Proceedings, PD Research Symposium	2002, 2003	3a	5.1, 2.2
240	Morgan, et al.	GWSS biological control in California: Research and application.	J. Insect Science (Tucson) 3(33): 15-16.	2003	3a	5.1
241	Morse	Seasonal population dynamics of GWSS egg parasitoids: variability across sites and host plants.			3a	5.1
242	Muniz, et al.	Overexpression, purification, biochemical characterization, and molecular modeling of recombinant GDP-mannosyltransferase (GumH) from *Xf*.	Biochemical & Biophysical Research Communications 315(2): 485-492.	2004	1a	3.1, 3.3

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					NAS	AVF
243	Nunney, Stouthamer, Luck	A genome-wide approach to plant-host pathogenicity in Xf: multigenic methods for identifying strains, for studying the role of inter-strain recombination, and for identifying pathogenicity candidate genes.			1a, 3b	3.1, 5.2
244	Nunney, Stouthamer, Luck	Genome-wide identification of rapidly evolving genes in *Xf*: key elements in the systematic identification of host strains, and in the search for plant-host pathogenicity candidate genes.	Proceedings, PD Research Symposium	2002, 2003	1a, 3b	3.1, 5.2
245	Orenstein, Zahavi, Nestel, Sharon, Barkalifa, Weintraub	Spatial dispersion patterns of potential leafhopper and planthopper vectors of phytoplasma in wine vineyards.	Annals Appl. Biol. 142(3): 341-348.	2003	1b	2.2, 3.3
246	Paula, et al.	Expression and purification of a putative H-NS nucleoid-associated protein from the phytopathogen *Xf*.	Protein Expression & Purification 32(1): 61-67.	2003	1a, 3b	3.1
247	Peloquin	Sharpshooter-associated bacteria that may inhibit PD.	Proceedings, PD Research Symposium	2001	3b	5.2
248	Perring	Epidemiological analyses of GWSS and PD data.			1a, 1b	3.3, 3.2
249	Perring	Treatment thresholds for GWSS based on the local epidemiology of PD spread.	Proceedings, PD Research Symposium	2003	1a, 1b, 3a, 5a	4.2, 3.3
250	Perring, Gispert	Epidemiology of PD in the Coachella Valley.	Proceedings, PD Research Symposium	2001, 2002, 2003	1a	3.3
251	Perring, Hashim	Development of a field sampling plan for GWSS vectored PD.			1b	3.3, 3.2, 4.1
252	Phillips	Timing and duration of fresh GWSS egg masses in lemon fruit rinds; impact on fruit harvest and shipments.			1c, 6	6, 5.5
253	Price	*Xf* bacterial polysaccharides with a potential role in PD of Grapes.	Proceedings, PD Research Symposium	2001	1a	3.3, 3.2
254	Purcell	Characterization and studies on the fundamental mechanisms of *Xf* transmission to grapevines by GWSS.	Proceedings, PD Research Symposium	2001, 2002, 2003	1b	2.2, 3.3
255	Purcell	Effects of chemical milieu on attachment aggregation, biofilm formation, and vector transmission of *Xf* strains.			1a	3.2
256	Purcell	Effects of sub-lethal doses of imidacloprid on vector transmission of *Xf*.	Proceedings, PD Research Symposium	2003	5b	5.3, 3.3
257	Purcell	Exploration for facultative endosymbionts of sharpshooters.	Proceedings, PD Research Symposium	2002, 2003	3a	5.1
258	Purcell	Fate of *Xf* in alternate hosts.	Proceedings, PD Research Symposium	2002, 2003	1a	3.3
259	Purcell	GWSS transmission of *Xf* to almond.	Proceedings, PD Research Symposium	2003	1b	3.2, 3.3

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					NAS	AVF
260	Purcell	Pruning for control of PD.	Proceedings, PD Research Symposium	2001	4, 6	5.5
261	Purcell	Role of bacterial attachment in transmission of *Xf* by GWSS, and other factors affecting transmission efficiency.	Proceedings, PD Research Symposium	2003	1a, 1b	3.2, 3.3
262	Purcell	Transmission of *Xf* to almonds by GWSS.	Proceedings, PD Research Symposium	2001	1b	3.2, 3.3
263	Purcell, Lindow	A screen for *Xf* genes involved in transmission by insect vectors.			1a, 1b	3.2, 3.3
264	Purcell, Lindow	Patterns of *Xf* infection in plants and effects on acquisition by insect vectors.	Proceedings, PD Research Symposium	2003	1a, 1b	2.2, 3.2, 3.3
265	Puterka	Alternatives to conventional chemical insecticides for control of GWSS.	Proceedings, PD Research Symposium	2001, 2002	5b	5.4
266	Puterka, Reinke, Luvisi, Ciomperlik, Bartels, Wendel, Glenn	Particle film, Surround WP, effects on GWSS behavior and its utility as a barrier to sharpshooter infestations in grape.	Online. Plant Health Progress doi:10.1094/PHP-2003-0321-01-RS. PuterkaPHP puterka03.pdf	2003	5b	5.5
267	Qin, Li, Hartung	Use of a triparental mating system to introduce green fluorescent protein marked transposon insertions in the plant pathogen *Xf*.	Proceedings, PD Research Symposium	2002	1a, 2b, 3b	5.2
268	Rakitov, Dietrich	Evolution and historical ecology of the Proconiini sharpshooters.	Proceedings, PD Research Symposium	2001	1b	2.1
269	Redak	Developing an IPM solution for PD spread by GWSS in Temecula.			3a	5.1, 5.5
270	Redak, Bethke	Pesticide screening against GWSS, using commercially available biorational, organic, and reduced risk pesticides.	Proceedings, PD Research Symposium	2003	5b, 3	5.3, 5.5
271	Redak, Bethke	Toward a standardized treatment protocol to eliminate GWSS egg masses in commercial nursery stock.	Proceedings, PD Research Symposium	2003	5b, 3	5.3, 5.5
272	Redak, Blua	Controlling the spread of *Xf,* the causal agent of oleander leaf scorch, by disrupting vector acquisition & transmission.			1b	3.3, 5.2
273	Redak, Blua	Impact of layering control tactics on the spread of PD by GWSS.	Proceedings, PD Research Symposium	2001, 2002, 2003	3, 5	5.5, 5.1
274	Redak, Purcell, Lopes, Blua, Mizell, Andersen	The biology of xylem fluid-feeding insect vectors of *Xf* and their relation to disease epidemiology.	Annual Review Entomol. 49: 243-270.	2004	1b	2.2, 3.3
275	Reisch, Cousins	Improving our understanding of substance transport across graft unions.			1c	5.6, 3.2
276	Reisch, Kikkert, Walker	Testing transgenic grapevines for resistance to PD.	Proceedings, PD Research Symposium	2003	2b	5.6
277	Ribeiro, et al.	Early photosynthetic responses of sweet orange plants infected with Xf.	Physiological & Molecular Plant Pathology 62(3): 167-173.	2003	1a	3.2

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Line Number	Principal Investigators	Title	Citation	Year	Research Categories	
					NAS	AVF
278	Ribeiro, et al.	High temperature effects on the response of photosynthesis to light in sweet orange plants infected with *Xf*.	Brazilian Journal Plant Physiology 15(2): 89-97.	2003	1a	3.2
279	Rodrigues, Silva-Stenico, Gomes, Lopes, Tsai	Detection and diversity assessment of *Xf* in field-collected plant and insect samples by using 16S rRNA and gyrB sequences.	Appl. Environ. Microbiol. 69: 4249-4255.	2003	1a	3.1, 3.3
280	Roper, et al.	Biochemical evidence of bacterial exopolysaccharide production in grapevines infected with *Xf*, the causal agent of Pierce's disease.	Phytopathology 93S(6S): 74-75.	2003	1a	3.2
281	Rosell, Costa	Ultrastructure of the bacteriome-associated endosymbionts of GWSS.	Proceedings, PD Research Symposium	2002	3a	5.1
282	Rost, Matthews, Stevenson	Mechanisms of PD transmission in grapevines: an analysis of the movement of *Xf* in xylem pathways.	Proceedings, PD Research Symposium	2002	1a, 1b	3.2
283	Rost, Matthews, Stevenson	Mechanisms of PD transmission in grapevines: relevance of hydraulic architecture.	Proceedings, PD Research Symposium	2003	1a, 1b	3.2
284	Scally, Schuenzel, Stouthamer, Nunney	The relative contribution of recombination versus point mutation in the plant pathogen *Xf*.	(in preparation)		1a, 3b	3.1
285	Schaad, et al.	*Xf* taxonomy.	Phytopathology 93S(6S): 76.	2003	1a	3.1
286	Schaad, Postnikova, Lacy, Fatmi, Chang	*Xf* subspecies: *Xf* subsp. *piercei* subsp. nov., *Xf* subsp. *multiplex* subsp. nov., and *Xf* subsp. *pauca* subsp. nov.	Systematic & Applied Microbiology 27(3): 290-300.	2004	1a	3.1
287	Shackel, Labavitch	Magnetic resonance imaging: a non-destructive approach for detection of xylem blockages in Xf-infected grapevines.	Proceedings, PD Research Symposium	2003	1a	3.2
288	Siebert	Economic impact of PD on the California grape industry.	Proceedings, PD Research Symposium	2001	6	6
289	Silva-Valdes, Portillo-Lopez, Stephano-Hornedo, Gould	Use of fluorescent recombinant antibodies for identification of *Xf*.	Proceedings, PD Research Symposium	2003	1a	3.2
290	Stevenson, Matthews, Greve, Labavitch, Rost	Grapevine susceptibility to PD II: the progression of anatomical symptoms.	(accepted, Amer. J. Enology Viticulture)		1a, 2a	3.2, 3.3
291	Stevenson, Matthews, Rost	Grapevine susceptibility to PD I: relevance of hydraulic architecture.	(accepted, Amer. J. Enology Viticulture)		1a, 2a	3.2
292	Stevenson, Matthews, Rost	The developmental anatomy of "green islands" and "matchsticks" as symptoms of PD of grapevines.	(submitted to Plant Disease)		1a	3.2
293	Stewart	Surrogate genetics for *Xf*.	Proceedings, PD Research Symposium	2002, 2003	1a, 3b	3.1
294	Stewart	Surrogate genetics for *Xf:* regulation of exopolysaccharide and type IV pilus gene expression.	Proceedings, PD Research Symposium	2001	1a, 3b	3.1
295	Toscano	Impact of neonicotinoids and an insect growth regulator on natural enemies of GWSS and other citrus pests.	Proceedings, PD Research Symposium	2003	5d	5.3

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					NAS	AVF
296	Toscano	Influence of environment & host plant effects on toxicity of insecticides to GWSS.			1a, 5a	2.2, 5.1
297	Toscano, Bi, Byrne, Castle	Plant-GWSS interactions: biochemical mechanisms involved in host plant selection between young and old orange trees.	Proceedings, PD Research Symposium	2003	1b	2.2
298	Toscano, Bi, Byrne, Castle	Plant-GWSS interactions: physiological and biochemical mechanisms involved in host plant selection with particular reference to lemon and orange trees.	Proceedings, PD Research Symposium	2002	1b	2.2
299	Toscano, Byrne, Castle	Laboratory and field evaluations of imidacloprid, thiamethoxam, and acetamiprid against GWSS on grapevines.	Proceedings, PD Research Symposium	2003	5a	5.3
300	Toscano, Castle	Laboratory and field evaluations of imidacloprid and thiamethoxam against GWSS on citrus and grapes.	Proceedings, PD Research Symposium	2001, 2002	5a	5.3
301	Toscano, Morse, Henneberry	Compatibility of insecticides with natural enemies of GWSS.			5a	5.3, 5.1
302	Toscano, Prabhaker, Byrne, Castle	Chemical control of GWSS: establishment of baseline toxicity and development of monitoring techniques for detection of early resistance to insecticides.	Proceedings, PD Research Symposium	2001, 2002, 2003	5a	5.3
303	Toscano, Prabhaker, Castle	Host plant influence on the reproductive ecology of GWSS and its susceptibility to insecticides.	Proceedings, PD Research Symposium	2003	1, 5a	2.2, 5.3
304	Triapitsyn	Prepare and submit for publication a pictorial, annotated key to *Gonatocerus* species and other genera and species of Mymaridae egg parasitoids of *Homalodisca* spp. and other Proconiine sharpshooters in N. America, with emphasis on the species native or introduced to CA.			3a	2.1, 2.2
305	Triapitsyn, Hoddle	Search for and collect egg parasitoids of GWSS in the southeastern USA and northeastern Mexico.	Proceedings, PD Research Symposium	2001, 2002	3a	5.1
306	Tubajika, Civerolo, Puterka, Bartels, Hashim, Luvisi, Wittenborn	Epidemiology of *Xf* diseases in California.	Proceedings, PD Research Symposium	2002	1a	3.3
307	Tubajika, et al.	Messenger and particle film Surround reduces Pierce's disease development in grape.	Phytopathology 93S(6S): 84.	2003	5b	5.5, 5.3
308	Van Sluys	*Xf* genome analysis - almond and oleander comparison to PD Temecula(1) and citrus strains.			1a	3.1
309	Velema, Hoddle, Hemerik, Luck	The influence of brochosomes on parasitization efficiency of *Gonatocerus ashmeadi* parasitizing *Homalodisca coagulata* egg masses.	(submitted to Ecological Entomol.)		3a	5.1
310	Vickerman, Hoddle, Triapitsyn, Stouthamer	Species identify of geographically distinct populations of the GWSS parasitoid *Gonatocerus ashmeadi*: morphology, DNA sequences, and reproductive compatibility.	Biological Control (in press)		3a	5.1
311	Walker	The genetics of resistance to PD.	Proceedings, PD Research Symposium	2001, 2002	2a	5.6

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					NAS	AVF
312	Walker, Krivanek, Riaz	Marker-assisted selection for resistance to *Xf*: accelerated breeding of PD resistant grapes.	Proceedings, PD Research Symposium	2003	2a, 2b	5.6, 3.2
313	Walker, Krivanek, Riaz	Optimizing marker-aided selection (MAS) for *Xf* resistance to accelerate the breeding of PD resistant grapes of high fruit quality.			2a, 2b	5.6
314	Walker, Ramming	The genetics of resistance to PD and breeding PD resistant table and raisin grapes.			2a, 2b	5.6
315	Walker, Riaz	An expanded genetic map of *Vitis rupestris* x *Muscadinia rotundifolia* for fine scale mapping and characterization of PD resistance.	Proceedings, PD Research Symposium	2002	2a, 2b	5.6
316	Walker, Riaz	Map-based identification and positional cloning of *Xf* resistance genes from known sources of PD resistance in grape.	Proceedings, PD Research Symposium	2003	2a, 2b	5.6
317	Walker, Ruel	Characterization of resistance to PD in *Muscadinia rotundifolia* selections including the potential for conferring resistance to grafted *Vitis vinifera* scions.	Proceedings, PD Research Symposium	2003	2a, 2b	5.6
318	Walker, Tenscher	Breeding PD resistant winegrapes.			2a, 2b	5.6
319	Walker, Tenscher, Ramming	Breeding PD resistant table and raisin grapes.	Proceedings, PD Research Symposium	2001, 2002	2a, 2b	5.6
320	Walker, Tenscher, Ramming	The genetics of, and breeding for, PD resistant grapes.	Proceedings, PD Research Symposium	2003	2a, 2b	5.6
321	Walters, et al.	Environmental monitoring of carbaryl applied in urban areas to control GWSS in California.	Environmental Monitoring and Assessment 82(3): 265-280.	2003	5b	5.3
322	Weber	Evaluation of blue-green sharpshooter flight height.			1	2.1
323	Weber	Trap crops for reducing spread of PD.	Proceedings, PD Research Symposium	2002	4a	5.5, 2.2
324	Weber, Toscano	Optimization of Admire applications in north coast vineyards.			5a	5.1
325	Wendel, Ciomperlik, Bartels, Lauziere, Stone-Smith, Luvisi, Elms	The area-wide pest management of GWSS in Kern County.	Proceedings, PD Research Symposium	2002	3, 5	5.1, 5.3, 5.5
326	Wong, Cooksey, Costa	Documentation and characterization of *Xf* strains in landscape hosts.	Proceedings, PD Research Symposium	2003	1a	3.2, 3.1
327	Workman, et al.	Marking and tracking GWSS in field studies.	J. Insect Science (Tucson) 3(33 Cited October 24, 2003): 29.	2003	1b	2.1, 4.1
328	Wulff, Carrer, Pacholati	Cloning and expression of cellulase XF-818 of *Xf* in *Escherichia coli*.	Scientia Agricola 60: 715-721.	2003	1a	
329	Yan, Habibi, Backus	AC and DC EPG waveforms of GWSS on *Chrysanthemum* and grape.	Proceedings, PD Research Symposium	2002	1b	2.1

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					NAS	AVF
330	Young	Rapid bioluminescent monitoring of infection by the PD agent.	Proceedings, PD Research Symposium	2003	1a, 1b	3.2, 4.2
331	Young, Igo	Plasmid addiction as a novel approach to developing a stable plasmid vector for *Xf*.			3b	5.2
332	Zalom, Peng	Reproductive biology and physiology of GWSS.	Proceedings, PD Research Symposium	2001, 2002, 2003	1b	2.1

APPENDIX G

PD/GWSS Research Recommendations Subcommittee

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